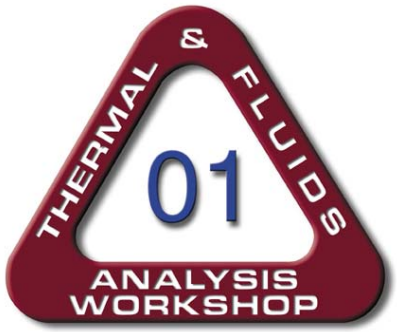


CONCEPTS NREC

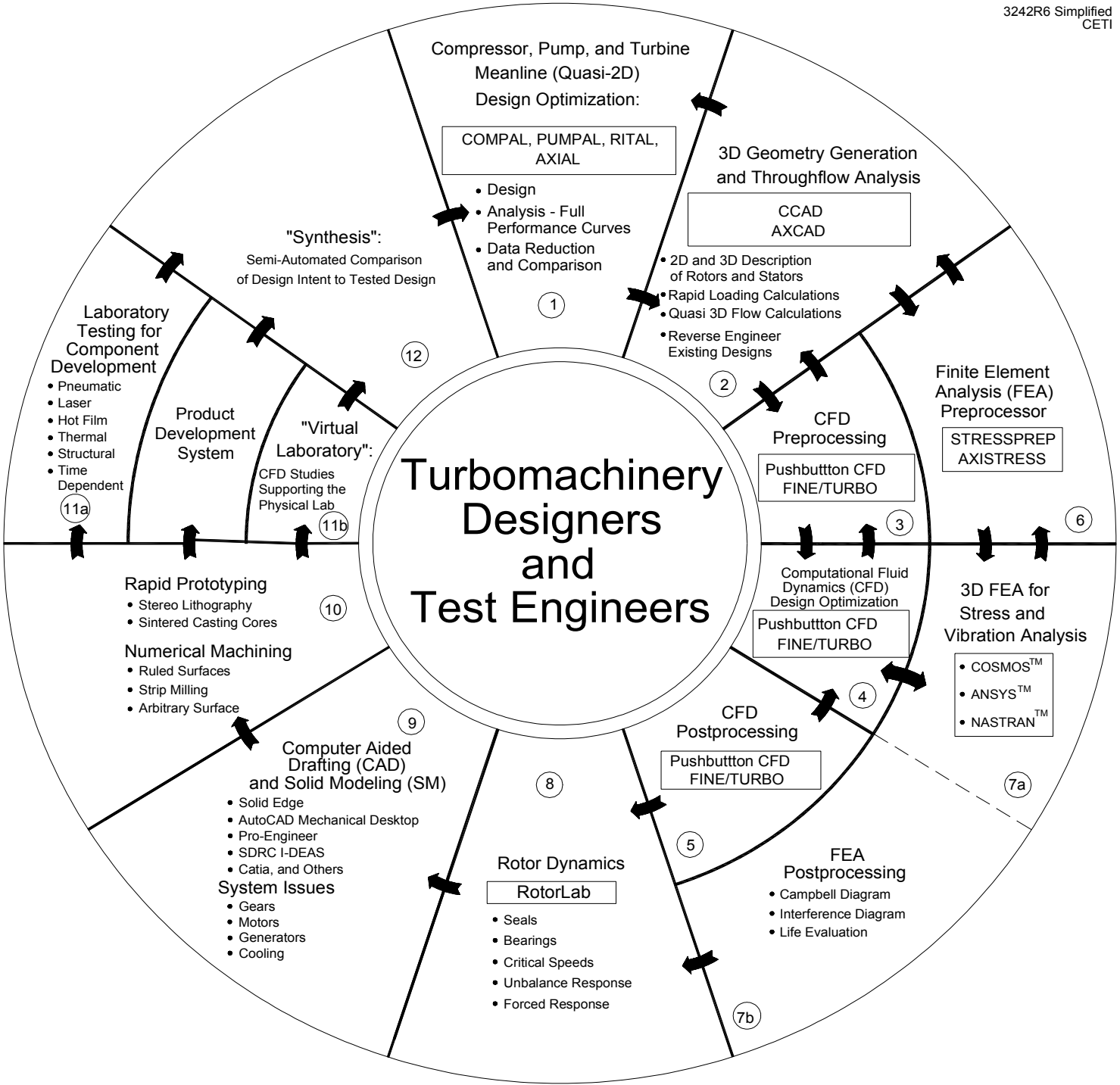
Integrated Turbopump Thermo-Mechanical Design and Analysis Tools

September 12, 2001

Mike Platt

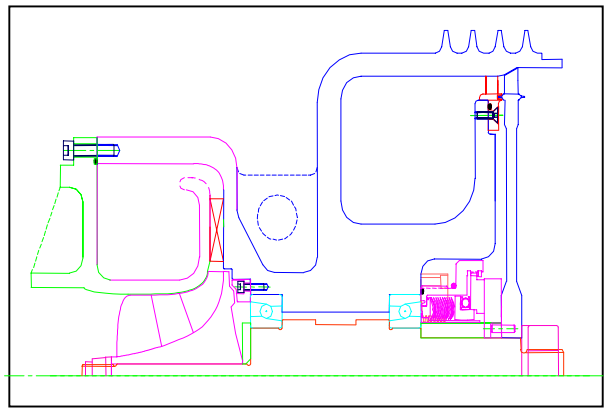
Summary

- Steady and transient thermo-mechanical effects drive life, reliability, and cost
- Design cycle needs upfront consideration of:
  - fits, clearance, preload
  - cooling requirements
  - stress levels, LCF limits, HCF margin
- Data synthesis is needed from component design tools


Turbomachinery Designers and Test Engineers
Compressor, Pump, and Turbine Meanline (Quasi-2D) Design Optimization:
COMPAL, PUMPAL, RITAL, AXIAL
• Design
• Analysis - Full Performance Curves
• Data Reduction and Comparison
1
3D Geometry Generation and Throughflow Analysis
CCAD
AXCAD
• 2D and 3D Description of Rotors and Stators
• Rapid Loading Calculations
• Quasi 3D Flow Calculations
• Reverse Engineer Existing Designs
2
CFD Preprocessing
Pushbuttton CFD
FINE/TURBO
3
Finite Element Analysis (FEA) Preprocessor
STRESSPREP
AXISTRESS
6
Computational Fluid Dynamics (CFD) Design Optimization
Pushbuttton CFD
FINE/TURBO
4
3D FEA for Stress and Vibration Analysis
• COSMOS™
• ANSYS™
• NASTRAN™
7a
CFD Postprocessing
Pushbuttton CFD
FINE/TURBO
5
FEA Postprocessing
• Campbell Diagram
• Interference Diagram
• Life Evaluation
7b
Rotor Dynamics
RotorLab
• Seals
• Bearings
• Critical Speeds
• Unbalance Response
• Forced Response
8
Computer Aided Drafting (CAD) and Solid Modeling (SM)
• Solid Edge
• AutoCAD Mechanical Desktop
• Pro-Engineer
• SDRC I-DEAS
• Catia, and Others
9
System Issues
• Gears
• Motors
• Generators
• Cooling
Rapid Prototyping
• Stereo Lithography
• Sintered Casting Cores
10
Numerical Machining
• Ruled Surfaces
• Strip Milling
• Arbitrary Surface
"Synthesis":
Semi-Automated Comparison of Design Intent to Tested Design
12
Laboratory Testing for Component Development
• Pneumatic
• Laser
• Hot Film
• Thermal
• Structural
• Time Dependent
11a
Product Development System
"Virtual Laboratory":
CFD Studies Supporting the Physical Lab
11b

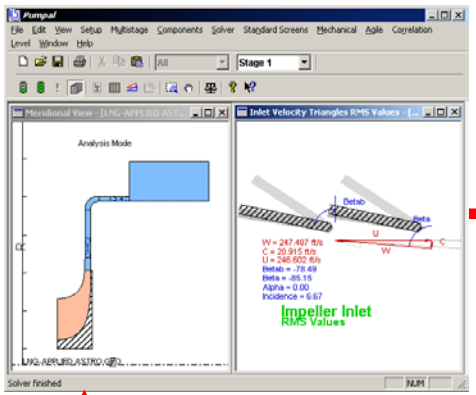
SBIR Tool Development

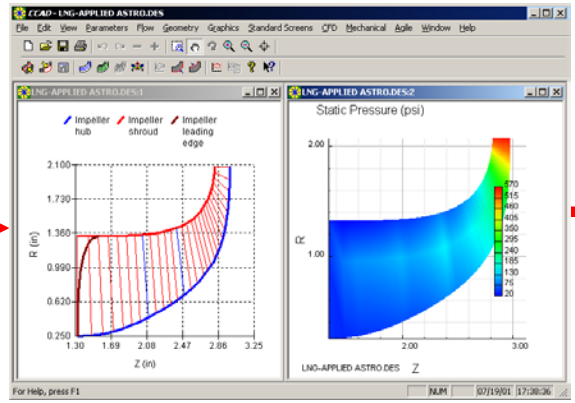
- Use LNG turbopump design during feasibility study
  - 630 gpm at 29.6 krpm
  - 37 lbm/s

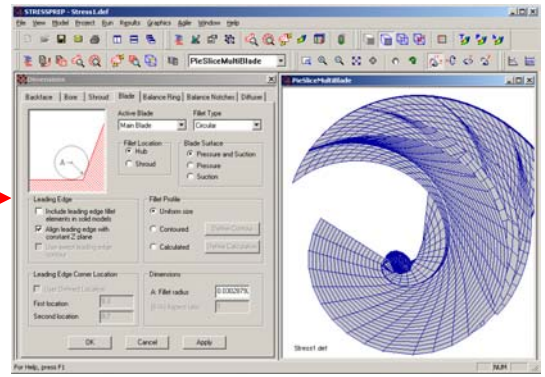


- Utilize existing component analysis tools to drive assembly models
- Integration into collaborative environment, not just interfacing separate tools

Current Design System



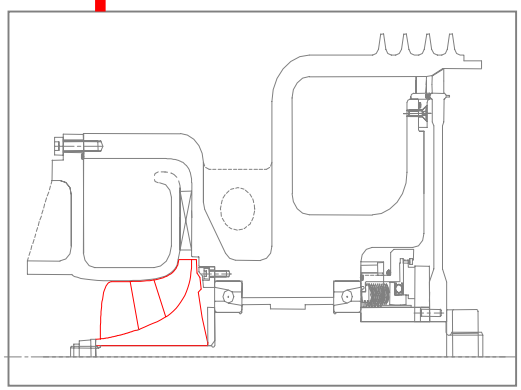




Meanline

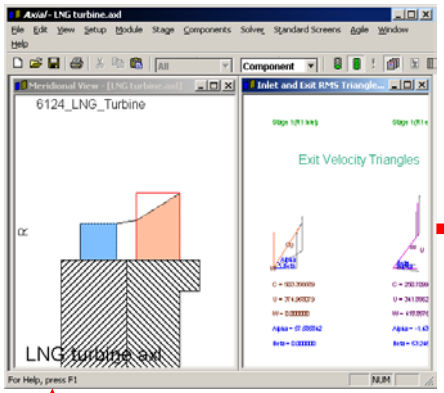
3D Blading & CFD

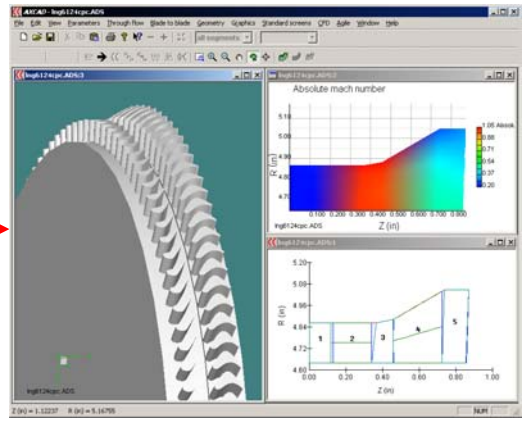
Stress & Vibration

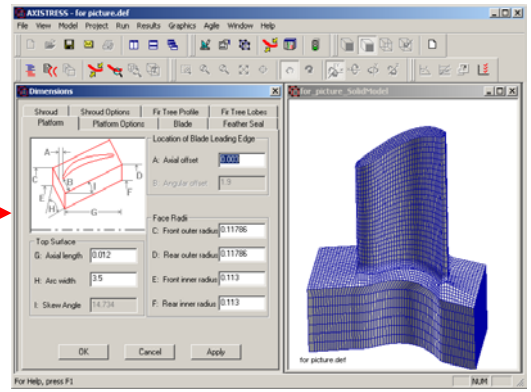


- Captures blade and disk stress, vibration, thermals
- Misses radial and axial preload effects, thermal conduction through bore

Current Design System



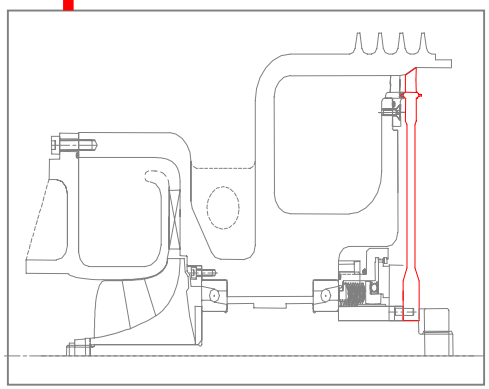




Meanline

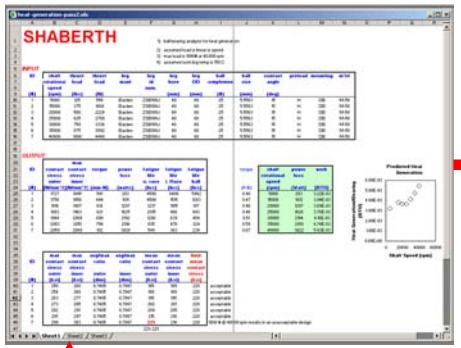
3D Blading & CFD

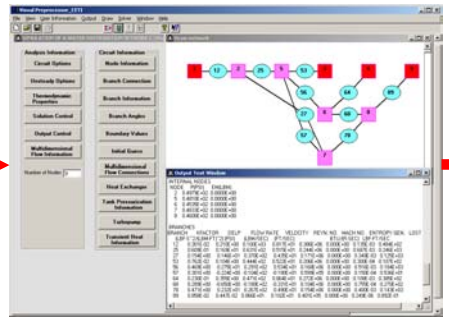
Stress & Vibration

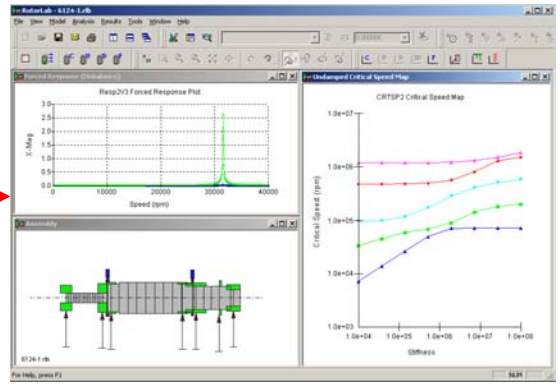


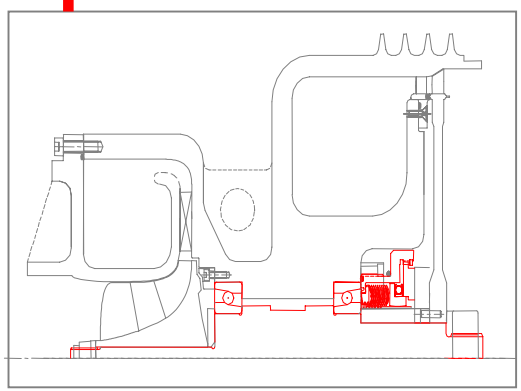
- Captures blade and disk stress, vibration, thermals
- Misses radial and axial preload effects, seal interaction, bore conduction

Current Design System



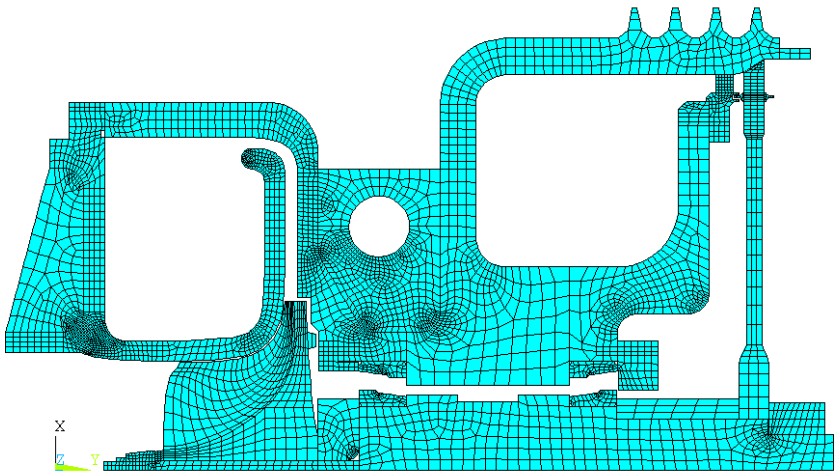






- Captures nominal bearing, seal, and shaft design
- Misses radial and axial preload effects

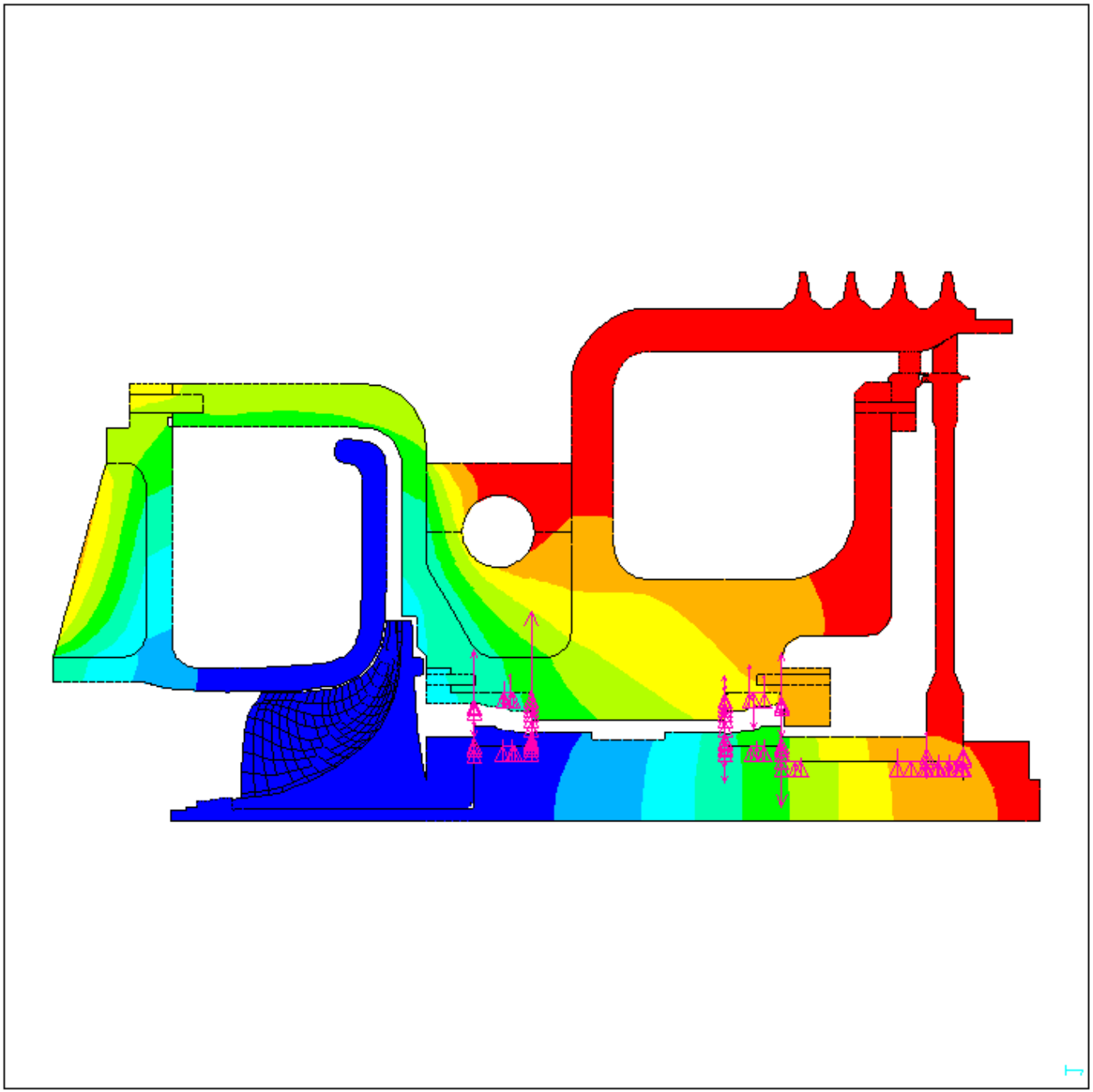
Thermo-Mechanical Design Tools

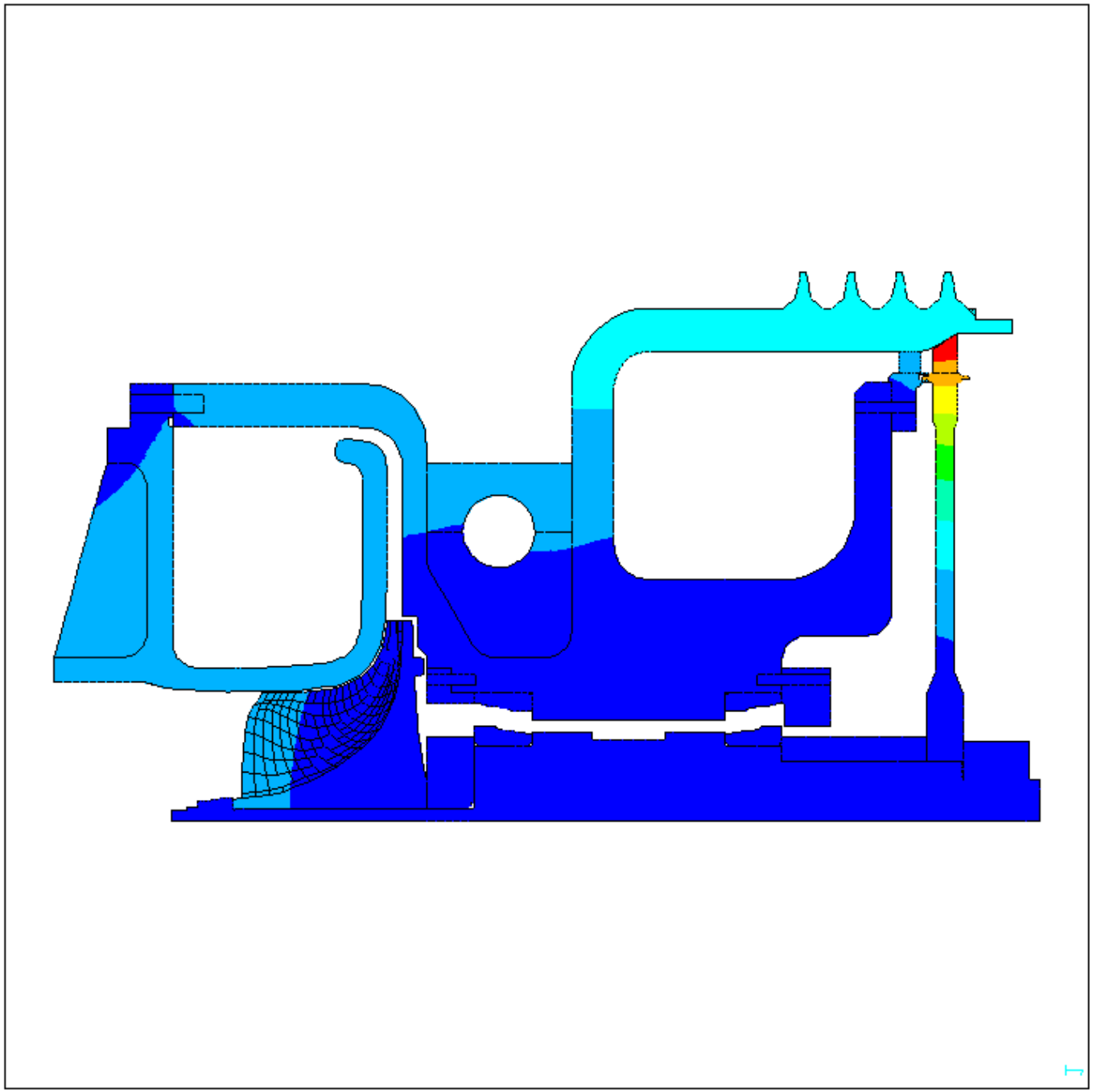


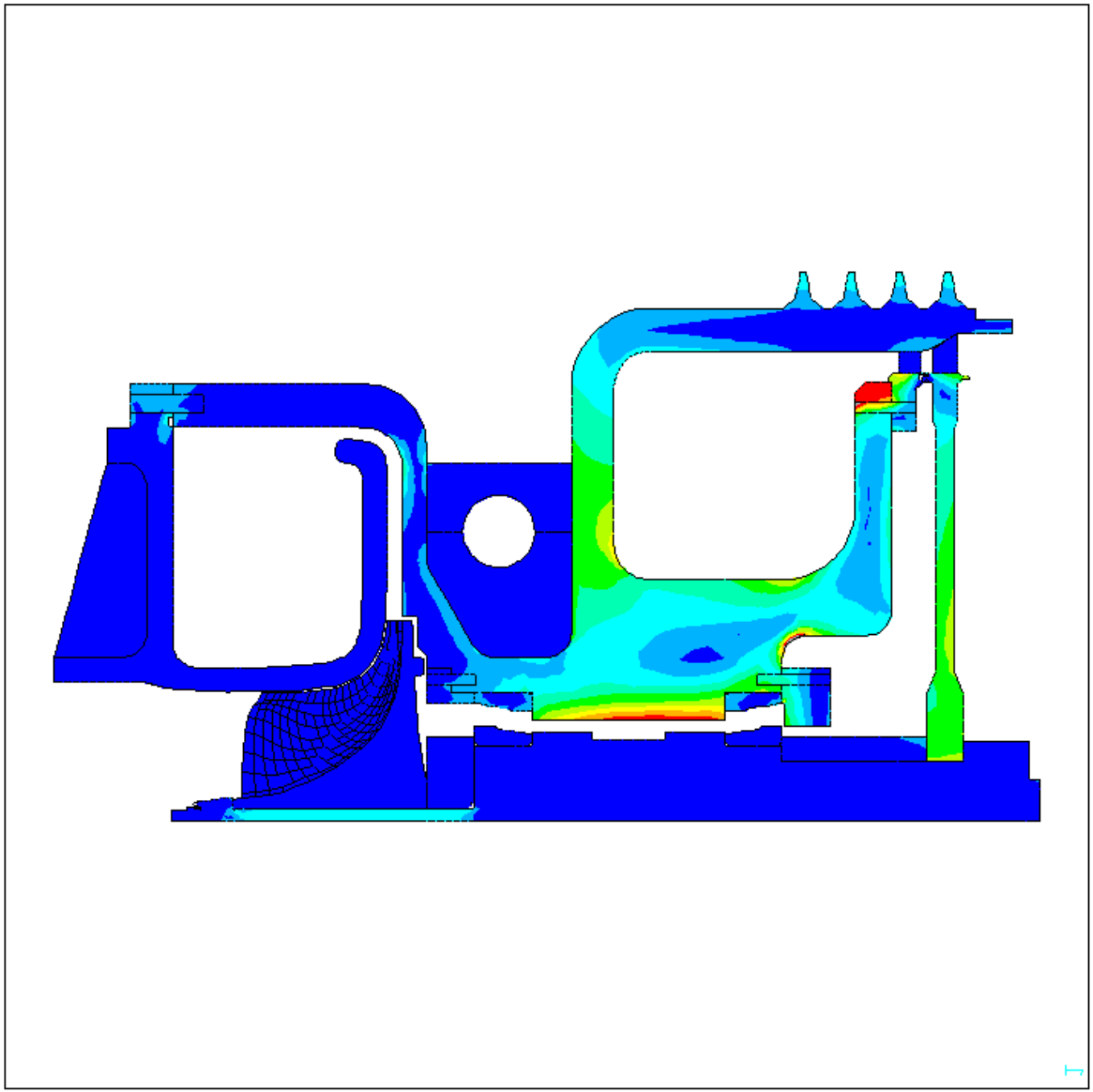
- Utilize data from component design tools
  - Rotor, shaft, housing geometry
  - Primary flow from pump and turbine
  - Internal cooling flow
  - Bearing, seal, and shaft design

Thermo-Mechanical Design Tools

- Temperature, stress, deflection
- Blade clearance, seal clearance, bearing race interference
- Thrust load, bearing preload
- Rotor clamp loads, shaft torque
- Stress results feed probabilistic models

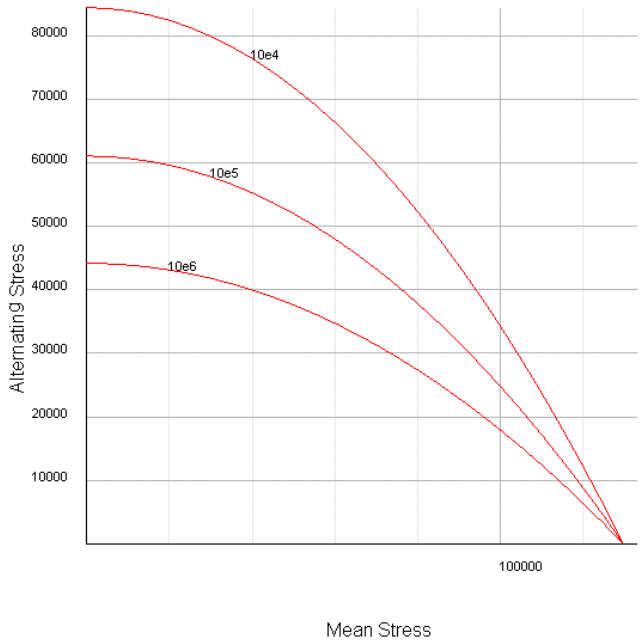

ANSYS 5.6.2
JUN 21 2001
08:03:11
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
SMN =-252
SMX =65.195
CE
NFOR
-252
-216.756
-181.512
-146.268
-111.024
-75.781
-40.537
-5.293
29.951
65.195


ANSYS 5.6.2
JUN 21 2001
16:30:04
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.122076
SMX =.122076
0
.013564
.027128
.040692
.054256
.06782
.081384
.094948
.108512
.122076

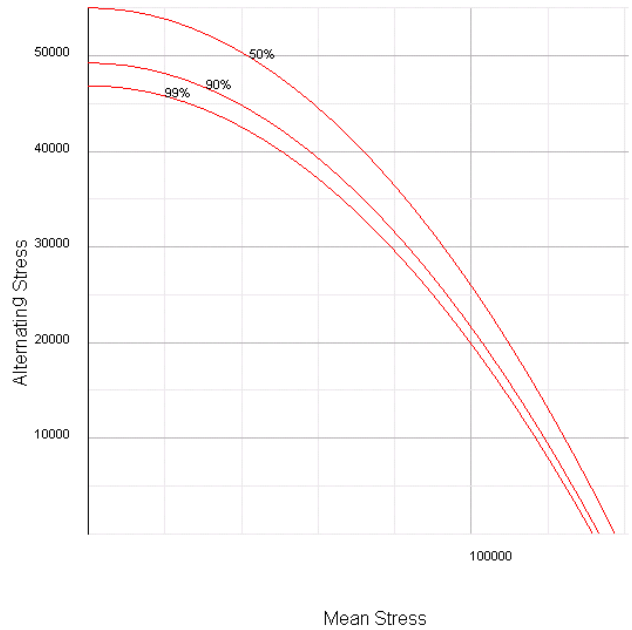

ANSYS 5.6.2
JUN 21 2001
16:27:47
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.122076
SMN =14.536
SMX =177818
0
16000
32000
48000
64000
80000
96000
112000
128000
144000

Life & Confidence Goals

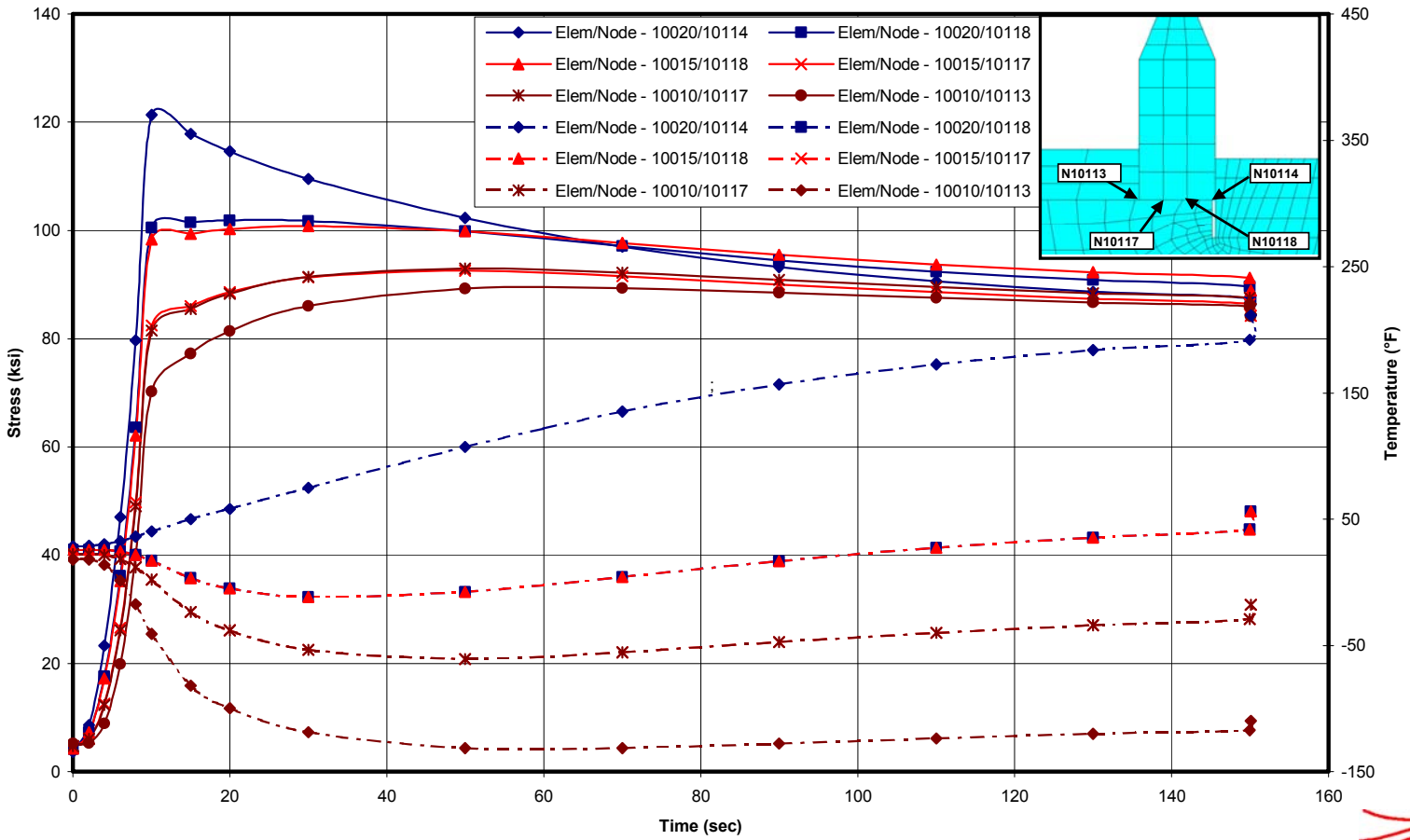
Fixed Confidence Level



Fixed Number of Cycles



Typical Transient Results

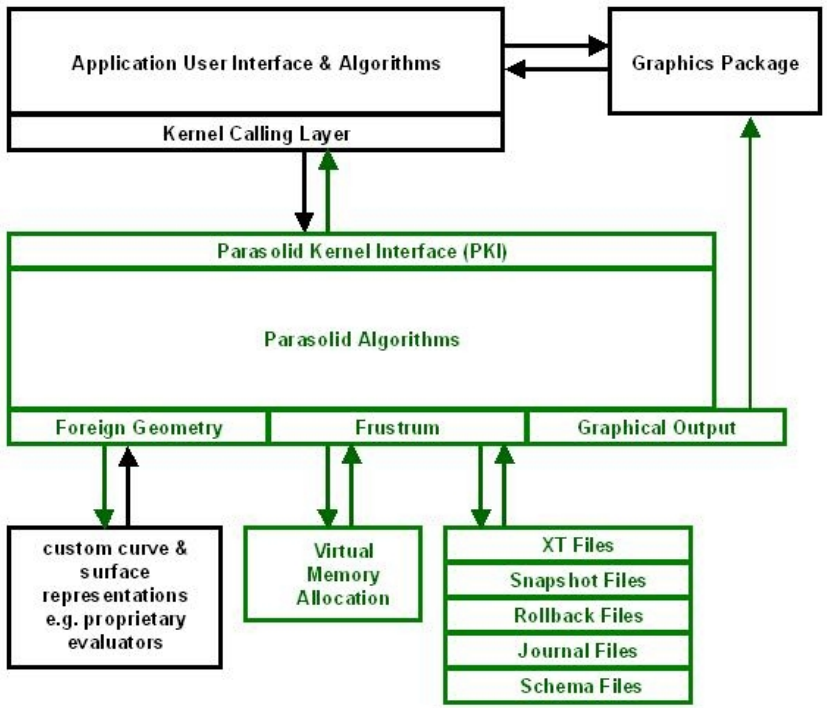


Goals for Design Tool Integration

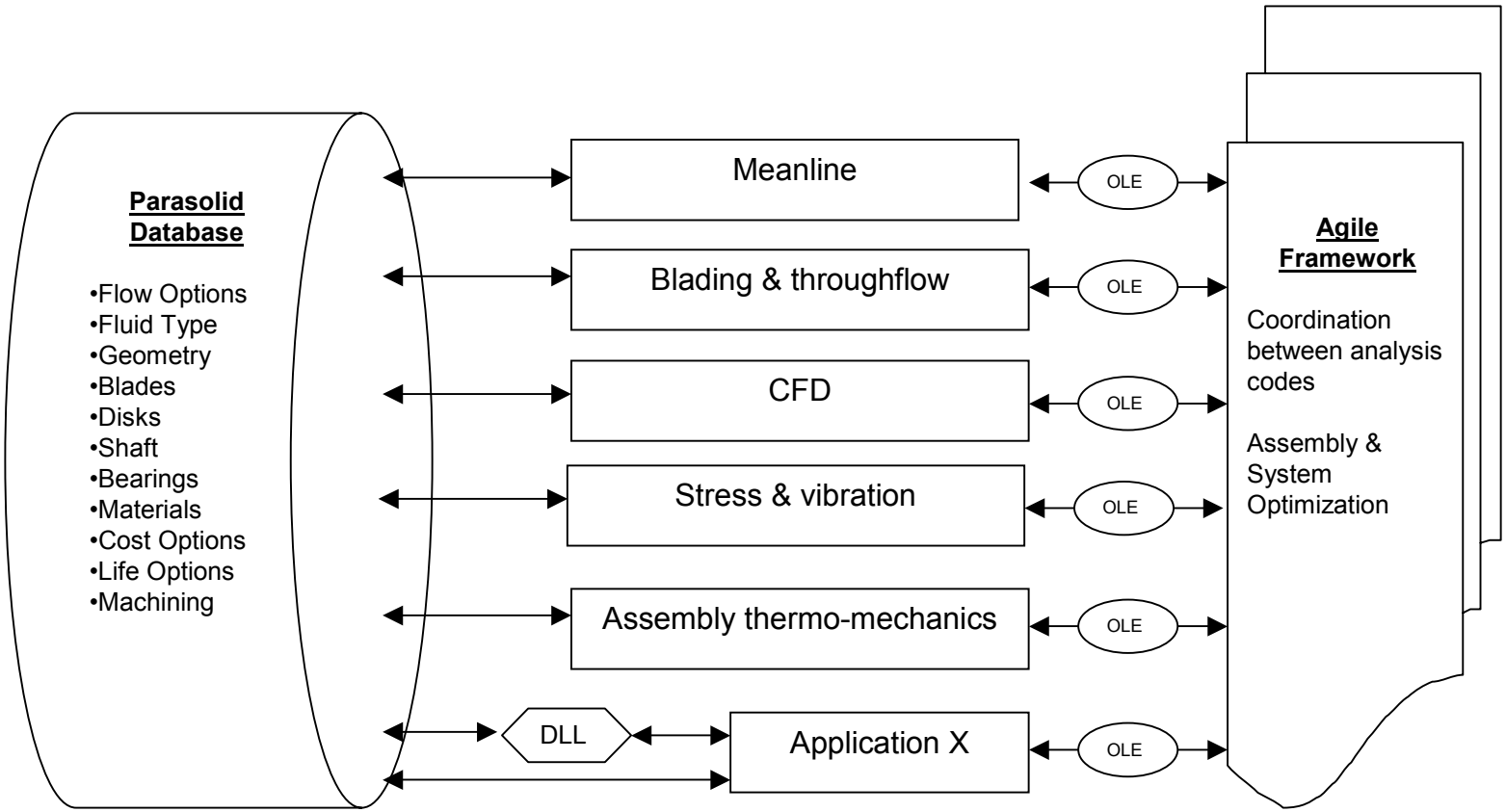
- Collaborative working environment
- Integrate with existing component design and analysis tools
- Direct data sharing, including CAD files
- Extensible to other solvers and applications
- Preserve intellectual property

Integration with CAD Kernel

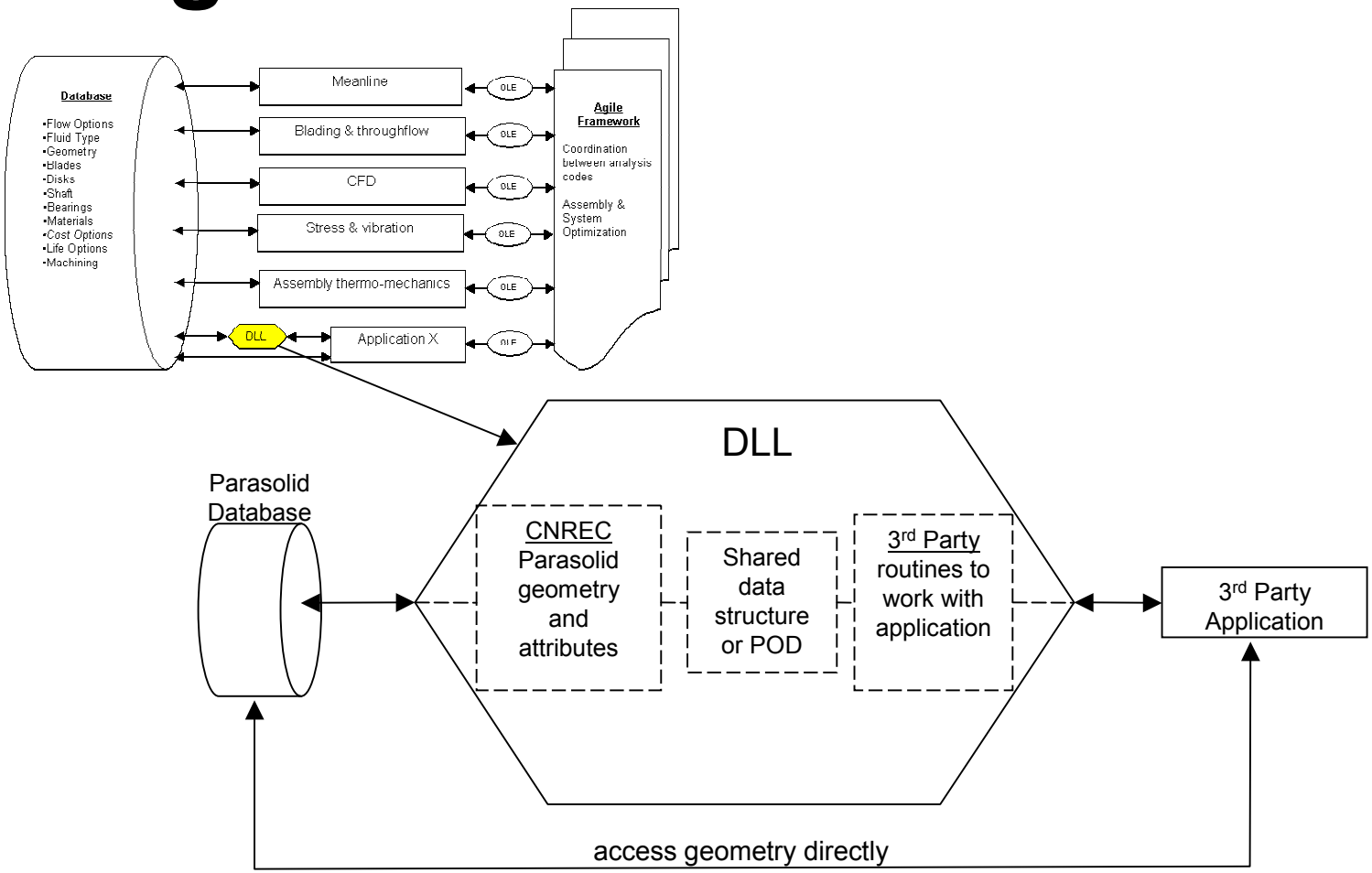
- Consistent and open data format
- Combine geometry and analytical results
- Direct support for native CAD files



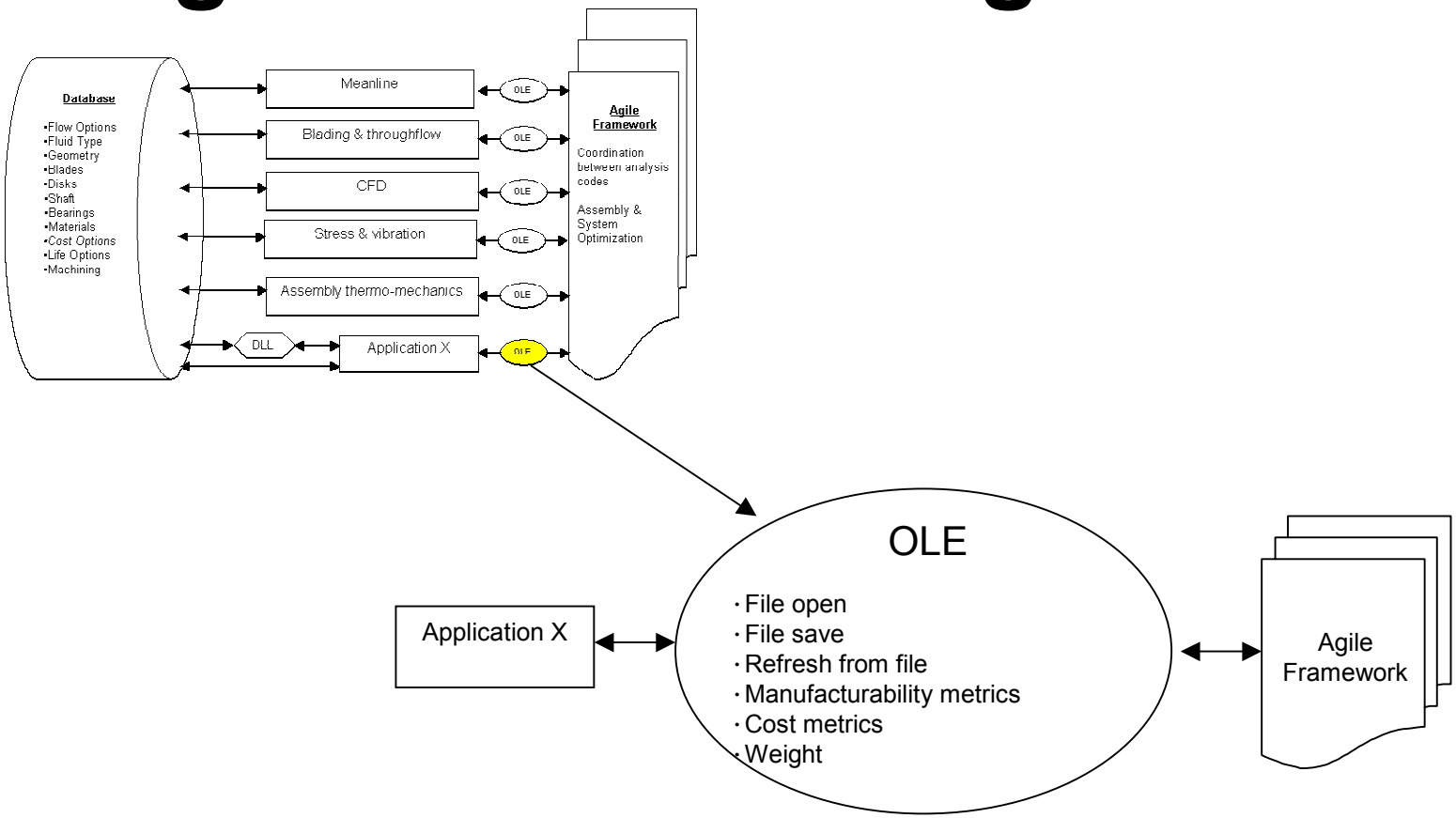
Design Tool Integration



Integration with Parasolid Data



Integration with Design Framework



Conclusions

- Thermo-mechanical analysis tool provides upfront design capability
- Existing component design tools are effectively leveraged
- Dual-use capability will give a broad user base
- Parasolid kernel allows collaboration with a wide applications base